SPRINGFIELD ARMORY



SPRINGFIELD, MASSACHUSETTS

RESEARCH AND ENGINEERING

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Report Title: Factors Influencing Friction of Phosphate Coatings

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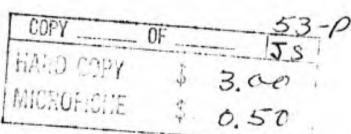
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Approved_

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Project Title: In-House Laboratory, etc.

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ABSTRACT

A friction and wear machine has been developed at Springfield Armory to simulate the frictional characteristics of reciprocating weapon components. The machine was used to evaluate the various factors influencing the friction of phosphate coatings. Coefficients of friction for the coatings were determined under static and dynamic conditions. The following factors influencing the coefficient of friction are considered: type of coating, lubrication, loading weight, surface roughness, crystalline structure, and velocity. The coefficients of friction for manganese phosphate coatings did not differ to any practical extent from the coefficients for zinc phosphate coatings. Lubrication is a significant factor on the coefficients of friction for phosphate coatings. The coefficient of friction was independent of the applied load. Velocity during dynamic testing, surface finish, and crystalline structure influenced the coefficient to a slight degree. Procedure is given, and results are discussed.

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SUBJECT

Factors Influencing Friction of Phosphate Coatings

OBJECTIVES

To investigate the various factors influencing the frictional behavior of phosphate coatings with the use of Springfield Armory reciprocating testing machine.

SUMMARY OF CONCLUSIONS

- 1. The testing apparatus will give adequate reproducibility of results.
- 2. A slight statistically significant difference was found between the mean static coefficient of friction for zinc phosphate (.876) and manganese phosphate (.913) coatings when unlubricated. This difference of 3 per cent is believed to have no practical significance.
- 3. Dry phosphate coatings have poor frictional characteristics and are not natural lubricants. Lubricated phosphate coatings with MIL-L-644 oil reduce the static coefficient of friction to approximately one sixth the value of the dry coating. The mean values are .145 for zinc phosphate and .147 for manganese phosphate.
 - 4. The static coefficient of friction is independent of load.
- 5. A comparison of the smooth dry phosphate coatings on a vapor-blasted surface with the dry phosphate coatings on a grit-blasted surface shows that the static coefficient of friction for the smoother surface (.858) is slightly less than for the grit-blast surface (.897). However, when the coating with vapor-blasting is oiled, its coefficient (.209) is greater than that for the oiled coating with grit blasting (.147).
- 6. Dry phosphate coatings with very coarse crystalline structures have a lower static coefficient of friction (.766) than standard coatings with a proper surface preparation (.913). The standard coatings have a lower coefficient when lubricated. The standard coatings have a mean coefficient of .147 as compared with a mean coefficient of .178 for the coarse crystalline roatings.

SUMMARY OF CONCLUSIONS - Continued

- 7. The maximum dynamic coefficient of friction for lubricated phosphate coatings during reciprocating motion approximates the static coefficient of friction. The mean static coefficients for lubricated zinc and manganese phosphate are .145 and .147, respectively; whereas, the mean maximum dynamic coefficients for zinc and manganese phosphate are .150 and .153 respectively.
- 8. Velocity has an effect on the dynamic coefficient of friction. The mean coefficients of friction at maximum velocity during the stroke were less than values at the ends of the stroke. The mean dynamic coefficients at maximum velocity were .113 for zinc phosphate and .116 for manganese phosphate.

RECOMMENDATIONS

- 1. All phosphate coatings should be lubricated to reduce friction.
- 2. As far as frictional properties are concerned, zinc and manganese phosphate coatings should be used interchangeably.
- 3. The effect of other lubricants on the frictional values of phosphate coatings should be studied.
- 4. Static coefficients of friction for lubricated phosphate coatings should be used to determine the maximum dynamic coefficient of friction present in reciprocating motion.
- 5. A quantitative study should be made of the relationship of velocity to the dynamic coefficient of friction.

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1. INTRODUCTION

It is easy to misinterpret some coefficients of friction. Handbooks list these coefficients for some combinations of materials, and a literature search will reveal more. Conditions under which the values were obtained are usually not given and "when they are, they seldom apply to a specific test condition. The quoted value may be in error from 25 per cent to as much as 200 per cent.1

At present, development and design engineers have only vague and meager information concerning frictional and wear properties of various coatings for use in designing weapons. The information which is available usually has been obtained from small pieces sliding on large circular discs under steady state conditions and is not necessarily applicable to reciprocating motion.

A friction-and-wear machine has been developed at Springfield Armory to simulate the actual wear of small caliber weapon components in motion. The machine reciprocates one block between two stationary blocks. This machine is designed to operate under loads from 32.1 pounds to 417.1 pounds, speeds from 600 r.p.m to 2000 r.p.m., and strokes up to approximately 2.5 inches.

Friction-and-wear considerations are very important in the functioning of weapons. For instance, in the M14 rifle, the movement of the bolt sliding on the receiver rails and the operating rod assembly sliding on the outside tracks of the receiver are examples of phosphate coatings sliding upon phosphate coatings. The M85 machine gun has chromium-plated wear components such as the slide breechblock and the barrel extension. Aluminum components are anodized and hard-anodized to increase the resistance to wear.

It has been proposed that measurements of the coatings used in weapons be evaluated with the use of Springfield Armory testing machine. A guide book for design engineers would be prepared on the information compiled. Phosphate, oxide, metallic, and organic coatings would be evaluated and the frictional values tabulated.

This report on the friction-and-wear project is concerned with the feasibility of using the friction machine to reproduce results, and the static and dynamic coefficients of friction for phosphate coatings. The scope of the investigation will include a comparison of zinc versus manganese phosphate, dry versus lubricated coatings, static coefficients versus dynamic coefficients, and the effect of load, surface roughness, and crystallinity on the coefficient of friction. The sample blocks used are similar to many standard weapon parts insofar as material, hardness, and surface finishing are concerned.

2. MATERIALS AND EQUIPMENT

- a. Springfield Armory Friction-and-Wear Testing Machine (Figs. 4 and 5), Dwg. No. SA-F-39615.
- b. Friction Blocks (Fig. 6), Material 4340 steel of Rockwell C hardness 45 to 50. Each set consists of two 3" by 2" by 3/8" blocks and one 1-1/4" by 1-1/4" by 1/2" block. Dwg. Nos. SA-F-39616 and SA-F-39617.
- c. Strain gages four 120 ohm gages connected as a Wheatstone bridge circuit.
- d. Strain gage amplifier Sanborn Model No. 64-500A with control panel Model No. 60-1600.
 - e. Recorder Sanborn Twin Viso Recorder Model No. 60-1300
 - f. Recording Paper Sanborn 2-channel Permapaper (Fig. 2).

3. PROCEDURE

a. Calibration of Friction Machine and Instrumentation

(1) Normal force

The normal force equals the load applied to the friction blocks. The load may be increased by the addition of weights to a tray attached to a lever arm. When no weights are added, the load consists of the weight of the upper friction block attached to its holder, and the reaction of the weight of the lever arm and weight tray applied at the point where friction occurs (See Fig. 1). This basic load was measured with a force indicator and found to be 32.1 pounds.

The lever arm acts as a second-class lever. The total length of the arm is 16.5 inches and the distance between the point at which the force is applied to the friction block and the weight tray is 15 inches. This results in a mechanical advantage for the arm of 11-1. Readings on the force indicator increased 11 pounds for each 1 pound weight on the tray and thus verified this reasoning.

PROCEDURE - Continued

(2) Friction force

The friction force is calculated from strain measurements obtained by the use of strain gages attached to the reciprocating rod which drives the moving friction block. In the calibrating of the equipment, this rod was placed under tensile and compressive loads with a tensile machine. Equal deflections in opposite directions on the recorder for similar loads were obtained under tensile and compressive conditions. A linear relationship between the load and the deflection on the recorder was obtained: a l-millimeter deflection corresponds to a 5-pound load.

(3) Force due to Acceleration

In reciprocating motion, forces due to acceleration are present because velocity is not constant. The rotary motion of the motor is changed to rectilinear motion by a crank-and-connecting-rod mechanism. A plot of velocity versus time for this mechanism gives a curve which approximates a sine wave. The maximum velocity would be approximately at the mid point of the stroke and zero velocity at the extremes of the stroke. The acceleration is 90 degrees out of phase with the velocity, thus zero acceleration exists at maximum velocity and maximum acceleration at the extremes.

The force due to acceleration was determined easily when the machine was operated with the middle block alone. Thus, the friction forces were eliminated. The acceleration forces were dependent upon the length of stroke and the number of revolutions per minute of the motor. A short stroke and a low motor speed were used so that the effect of acceleration could be minimized. The values selected for all dynamic tests were a 1-inch stroke and 600 r.p.m. Under these conditions, the maximum recorder deflection for one cycle of movement was estimated to be only 1 millimeter.

PROCEDURE - Continued

b. Preparation of Test Specimens

(1) Machining

The 4340 steel blocks used in the testing were heat treated and quenched to a final hardness of Rockwell C 45 - 50. Final surface grinding produced surfaces that were parallel within .0002 inch and gave surface roughness values of 4 to 6 microinches (r.m.s.) as measured on a profilometer.

(2) Surface Preparation

The specimens after degreasing were abrasive blasted with steel grit (number 120). An exception to this procedure occurred in the surface roughness study when two alternate blasting techniques were used. A vapor-blast with the use of abrasive number 200 and a table grit-blast with a mixture of steel grit (numbers 50 and 80). No blasting was necessary for the coarse crystalline coatings since a 50 per cent hydrochloric acid dip was used.

(3) Phosphating

The phosphating of the specimens was accomplished in a standard laboratory bath. The manganese phosphate solution had the following controls: total acid 55 - 65 points, free acid 10 - 11 points, and iron .1 to .3 per cent. The zinc phosphate solution had the following controls: total acid 28 - 30 points, free acid 4 - 6 points, and iron .1 to .3 per cent. The blocks were phosphated for 30 minutes in a bath at 205° F. A hot water rinse and a chromic acid rinse followed. The lubricated blocks were dipped in oil conforming to specification MIL-L-644.

c. Friction Testing

Proper balancing of the instrumentation was necessary before each series of tests. When the blocks were placed in the friction machine, some adjustments were necessary to obtain even wear. This was accomplished by the adjustment of 8 rollers which control the placement of the holder of the upper friction block (Fig. 1).

PROCEDURE - Continued

After an adequate wear pattern had been achieved, the movable block was pushed back and forth several times to break in the coating. Initial friction values are not considered important since phosphate coatings usually offer rapid break in qualities.

Static friction conditions were simulated by pushing the movable block by hand back and forth at a slow rate. Weights were added to the tray in 1-pound increments. The dynamic tests were operated at 600 r.p.m. and a 1-inch stroke. The weights were added to the tray in 5-pound increments. The total maximum recorder deflection for both the static and dynamic testing and the corresponding loads were tabulated. Values at the center of the stroke were also taken in the case of dynamic runs.

d. Calculation of the Coefficient of Friction

The coefficient of friction is determined by dividing the friction force by the normal force. The normal force is the basic load, 32.1 pounds, plus 11 times the weight applied to the weight tray.

The friction force is calculated from the maximum deflection on the recorder for one cycle of movement (Fig. 2). In the case of the dynamic trials, the deflection value representing the force due to acceleration must be subtracted before friction calculations. This correction is unnecessary for the mid-stroke deflection since, theoretically, the acceleration is zero at this point.

The deflection must be divided by 2 since a compressive and a tensile force are applied in the reciprocating motion of the block. Also, the deflection must be halved again since two separate friction forces are developed in opposing the motion of the movable block. One of the friction forces results from the contact of the upper stationary block with the upper surface of the movable block. A similar condition exists at the lower surface of the moving block and the lower stationary block (Fig. 1).

The two friction forces are assumed to be equal. These forces differ slightly in that, at the lower surface, the load has increased by the weight of the middle block. Since the middle movable block weighs only 1/4 pound, this factor is neglected.

PROCEDURE - Continued

The friction force in pounds thus can be determined by dividing the total deflection by 4 and multiplying by the calibration factor of 5 pounds per millimeter.

When high friction forces were present it was necessary to change the attenuator on the amplifier from the 1 scale to the 4 scale. This, in essence, cut the deflection fourfold and increased the calibration factor to 20 pounds per millimeter.

4. RESULTS AND DISCUSSION

a. Reproducibility of Results

A reproducibility study was conducted with the use of zinc and manganese phosphate coatings in both the dry and the lubricated condition. A total of 5 static trials with each trial having 16 different loads were run for the dry coatings. The lubricated coatings had 4 static trials with each trial containing 36 different loads. Since load had no apparent effect on the coefficient of friction, as shown later, mean values were calculated.

Standard deviations for the results on each different coating were also calculated and are found in Tables I through IV. The largest deviation was noted in the results for tests on dry manganese phosphate coatings. The deviation from the mean was ±.049 when the mean coefficient of friction was found to be .913. The 95 per cent confidence level for the mean of large samples equals 1.96 times the standard deviation. Thus, the confidence limits of 95 per cent for the coefficient of friction of dry manganese phosphate coatings are approximately .81 and 1.01. This indicates adequate reproducibility of the results if the possible errors in the experimental method are concerned. The probable cause for much of the experimental error is in the reading of the recorder deflection.

A friction study by the Jet Propulsion Laboratory at the California Institute of Technology showed a similar degree of reproducibility. Coefficients of friction near 1.00, found by the Jet Propulsion Laboratory, had an estimated standard deviation of ±.05 and friction coefficients near 0.20 had an approximate deviation of ±.035.

RESULTS AND DISCUSSION - Continued

The dynamic testing did not yield reproducible results for the dry coatings. The high friction forces resulted in galling, and erratic results were obtained.

Results were obtainable for the lubricated phosphate coatings under dynamic conditions. The results, however, were not as consistent as those for the static tests. For example, the mean value of the dynamic coefficient of friction for lubricated manganese phosphate was .153 \pm .046. The static coefficient of friction for the same coating was .147 \pm .011.

b. Comparison of Zinc versus Manganese Phosphate

A large amount of data was compiled on zinc and manganese phosphate coatings to determine whether a difference exists between the two coatings in frictional characteristics. The mean static coefficient of friction for dry manganese and dry zinc phosphate were .911 and .876, respectively. Lubricated manganese phosphate gave a mean coefficient of .147, whereas the lubricated zinc phosphate gave .145. The complete data can be found in Tables I through IV.

It is difficult to determine whether there is a significant difference between the zinc and manganese phosphate on the basis of mean values alone. The "t" test can be used to determine whether the mean of one set of values is significantly different statistically from the mean of another set.

With the "t" test as a basis for comparison, the mean values for dry zinc phosphate coatings were significantly different from dry manganese phosphate coatings. The "t" test indicated that dry zinc phosphate coatings had slightly improved frictional properties over dry manganese phosphate. The value of t calculated for the dry coatings exceeded the table value at the 99 per cent level. Thus, there is over a 99 per cent degree of assurance that the mean of the zinc phosphate differs from the mean of the manganese phosphate.

A similar "t" test was made on the lubricated coatings. No significant difference between the zinc and manganese phosphate coatings in the lubricated state was found. The mean values of the dynamic coefficients also substantiated the fact that there is no difference between zinc and manganese phosphate when lubricated.

RESULTS AND DISCUSSION - Continued

During the static friction testing, the dry manganese phosphate coatings powdered more than the dry zinc phosphate coatings. This resulted in some bare spots in the coating at the conclusion of the test. This possibly was due to the fact that the zinc phosphate was a thicker coating.

Most of both coatings were worn off at the conclusion of the dynamic testing. The coefficient of friction did not appear to be dependent upon the amount of coating worn off just as long as the coating retained a sufficient amount of oil to maintain good lubrication.

Lubricated manganese phosphate coatings, during dynamic testing, were broken in almost immediately. The zinc phosphate coatings generally required 30 seconds to a minute to completely break in the coating and give a constant coefficient of friction.

c. Effect of Load

The load was varied during the static testing from 32.1 pounds to 417.1 pounds. This represents pressures from approximately 50 pounds per square inch to 670 pounds per square inch. In some trials, the load appeared to have a slight effect on the coefficient. In these instances, however, an increase in load sometimes resulted in an increase and sometimes, a decrease in the coefficient. This phenomenon was probably due to the fact that the rollers, used to align the friction blocks, had a tendency to support a small part of the load. It was concluded that the load did not significantly affect the coefficient of friction. Tichvinsky has shown that the coefficient is independent of load for hard steel on hard steel and nickel on mild steel over a similar range of load.

During the dynamic tests, the load was varied from 32.1 to 307.1 pounds. The coefficient of friction did not appear to be dependent upon the load except for one load of 197.1 pounds. At this particular load, the coefficient was always higher. It is believed that this increased value was due to slight tilting of the upper friction block which caused uneven wear. Further investigation is necessary to determine the exact nature of the high friction forces at 197.1 pounds. The friction values at this load were discounted in the determining of the mean dynamic coefficients of friction since the probable cause of the discrepancy was of a mechanical nature.

RESULTS AND DISCUSSION - Continued

d. Effect of Lubrication

It is evident that phosphate coatings with MIL-L-644 oil have vastly improved frictional characteristics over dry coatings. Lubrication reduced the static coefficient sixfold from its value in the dry state. Goodman has stated in his Laws of Friction for Lubricated Surfaces that the coefficient of friction of well-lubricated surfaces is from 1/16 to 1/10 that of dry or poorly lubricated surfaces. This indicates that phosphate coatings are not natural lubricants. The advantage is that these coatings act as excellent retainers for lubricants and offer fast break-in qualities.

e. Effect of Surface Roughness

Three different surface preparations were used prior to phosphating. Vapor-blasting with an SiO₂ abrasive (No. 200) produced a surface roughness of 14 to 16 microinches (r.m.s.). After phosphating, the roughness was raised to 30 to 32 microinches (r.m.s.). Grit-blasting with steel grit (No. 120) gave profilometer readings of 55 to 65 microinches, whereas grit blasting with a mixture of numbers 50 and 80 gave readings of 60 to 70 microinches. The surface roughness readings after phosphating for the different grit-blasted surfaces, however, were the same (50-60 microinches r.m.s.).

The static coefficient of friction did not vary between the grit blasted samples. These data can be found in Table V. The smoother phosphate surface produced by vapor-blasting did slightly lower the coefficient for dry coatings. The mean coefficient was .858 as compared with .897 and .899 for the grit-blasted surfaces. This difference was proved to be statistically significant with the use of the "t" test.

The results for smooth phosphate coatings in the lubricated state can be found in Table VI. Comparison of the results in this table with those of Table III shows that the coefficient has increased for the smoother surface. This possibly indicates that a smoother phosphate coating is not completely effective as a retainer for lubricants.

RESULTS AND DISCUSSION - Continued

f. Effect of Crystalline Structure

Coarse crystalline manganese phosphate coatings were obtained by using a 50 per cent hydrochloric acid dip before phosphating instead of blasting. The static coefficients for these coatings can be found in Table VII. Comparison of the coarse crystalline coatings with the values of the standard coatings in Tables I and III showed that the dry crystalline coatings exhibited better frictional characteristics than the standard coatings. The dry coarse crystalline coating is harder and more brittle than a normal phosphare coating, thus peaks are easily fractured and less resistance to sliding is present.

In the lubricated state, however, the coarse coatings had a higher mean coefficient than the standard manganese phosphate coatings. These data appear to contradict the results discussed in the previous section since the smoother coatings also had a higher mean coefficient. This leads one to believe that an optimum crystal size or roughness exists for the lubricated phosphate coating naving the best frictional characteristics.

g. Comparison of Static and Dynamic Coefficients

Tables of friction coefficients found in standard compilations generally show that the static coefficients are approximately 40 per cent greater than the dynamic coefficients. A comparison of the static and dynamic coefficients found in Tables III, IV, VIII and IX shows that the mean dynamic coefficients approximate the mean static coefficients. The mean static coefficients for zinc and manganese phosphate are .145 and .147, respectively, whereas the mean maximum dynamic coefficients for zinc and manganese phosphate are .150 and .153, respectively.

Rabinowicz states that for some sliding combinations there is no difference between the static and the dynamic coefficients. Some movement of a stationary system will occur, even on application of a value of the friction force smaller than that corresponding to the dynamic coefficient. In essence, the breakaway coefficient equals the dynamic coefficient for the initial sliding speed. Lubricated phosphate coatings appear to be surfaces that behave in this manner.

RESULTS AND DISCUSSION - Continued

During the dynamic testing, the recording paper speed was increased. This increased speed made it possible to record the change in friction force with velocity for the reciprocating movement. It was noticed that the friction force at low loads appeared to reach a minimum value at the center of a stroke, the point at which velocity is a maximum (Fig. 3). At high loads, the recordings showed the friction force to be a maximum at one end of the stroke and a minimum at the other end. The maximum friction force for the load with apparent uneven wear occurred at the middle of the stroke. Further investigation is necessary to determine whether these differences are due to mechanical alignment of the friction blocks or actually frictional phenomenon.

Coefficients of friction were determined from the mid stroke deflections. The mean coefficient for zinc phosphate was .113 and for manganese phosphate .116. These values indicate that the dynamic coefficient is dependent upon velocity.

APPENDICES

REPORT SA-TR18-1084

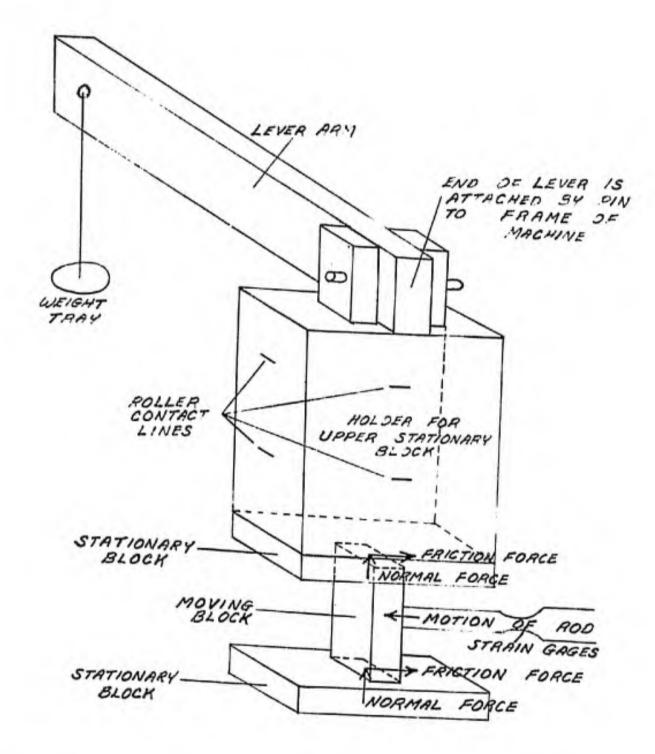
Appendix A - Figures (6)

Appendix B - Tables (9)

Appendix C - Bibliography

Appendix D - Distribution

APPENDIX A - Figures



NOTE I) THE ROLLERS ARE ATTACHED TO THE FRAME WHICH ENCLOSES THE HOLDER FOR THE UPPER STATION-

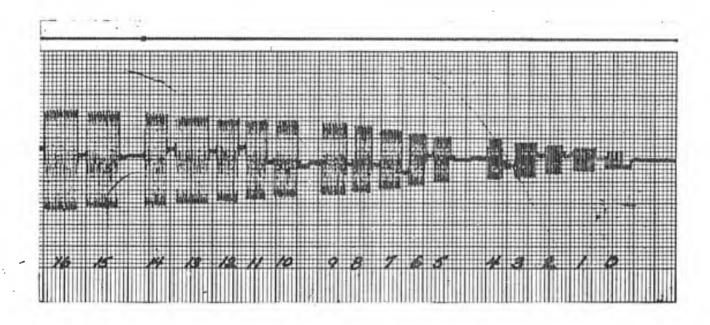
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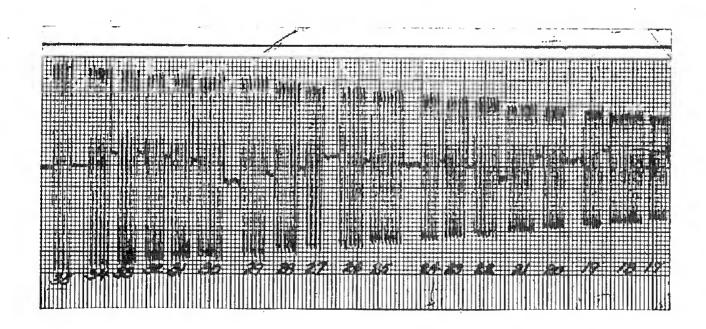
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FIGURE 2 TYPICAL RECORDER DEFLECTIONS

FOR A STATIC TRIAL USING LUBRICATED MANGANESE PHOSPHATE BLOCKS. LOAD ON LEVER ARM

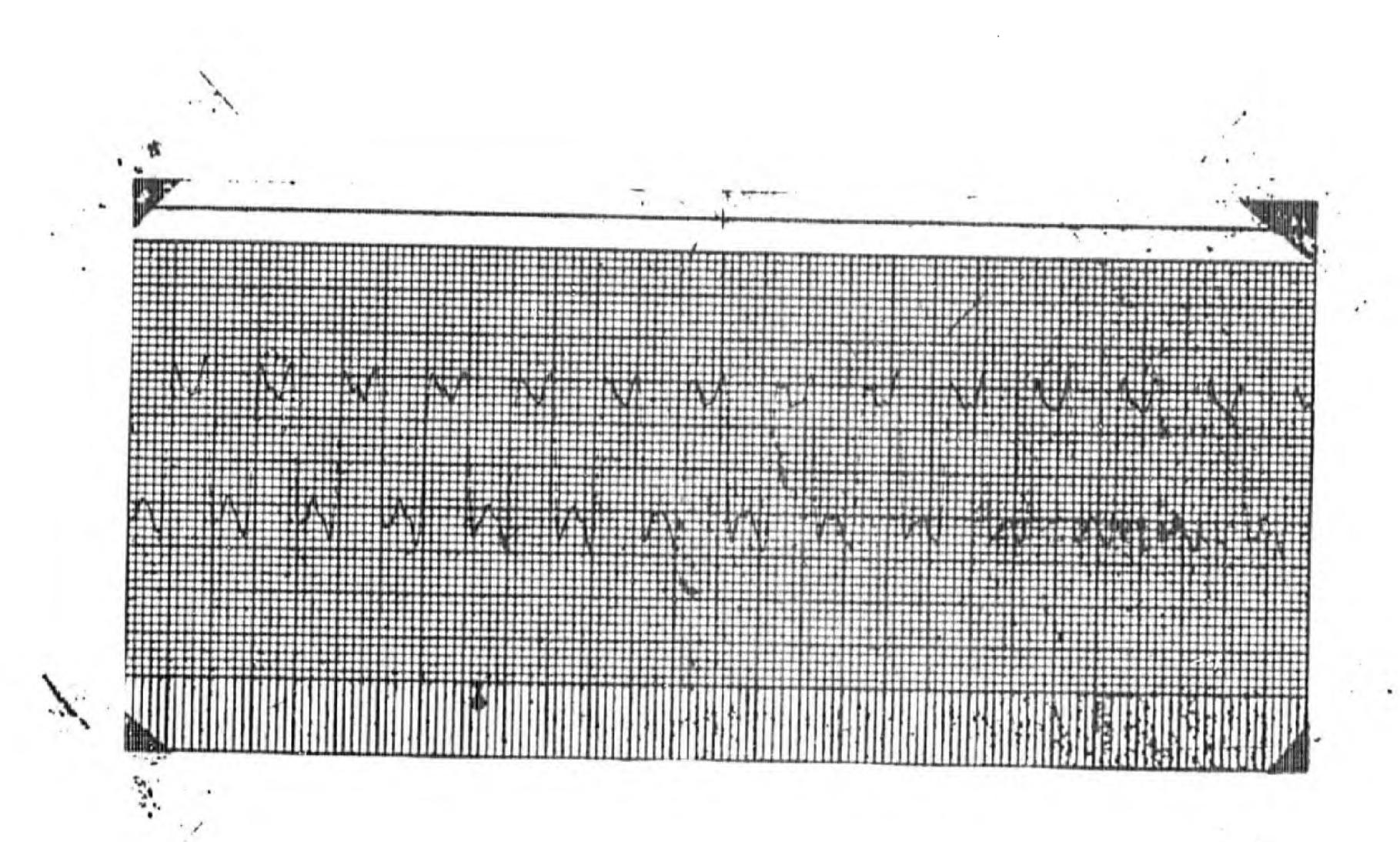
INCREASED FROM O TO 35 LBS. IN ONE LB. IN
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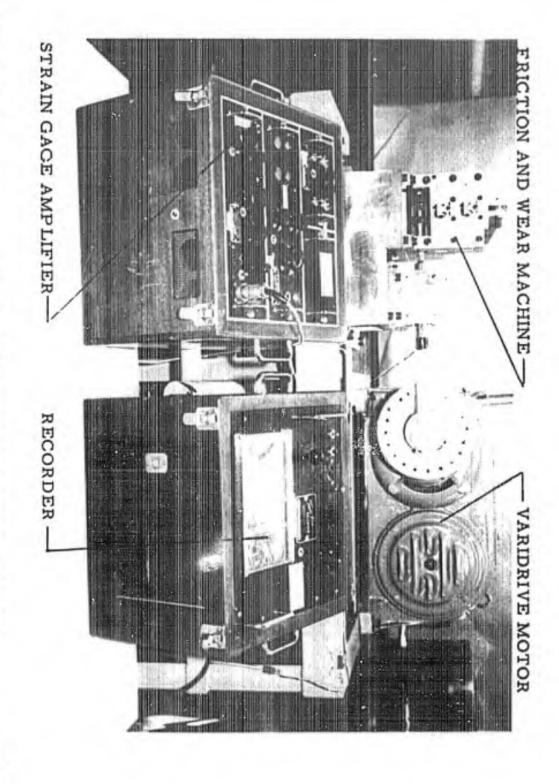


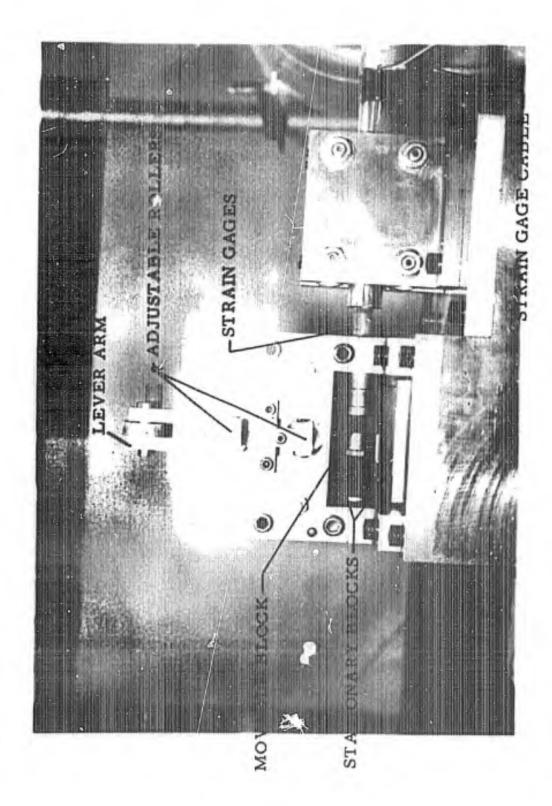
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FIGURE 3 TYPICAL RECORDER DEFLECTION FOR

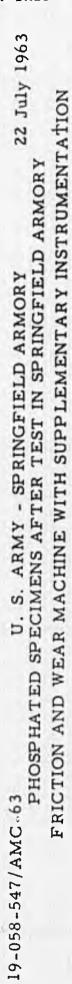
A DYNAMIC TRIAL USING LUBRICATED ZINC PHOSPHATE BLOCKS. LOAD ON LEVER ARM IS 10 LBS.

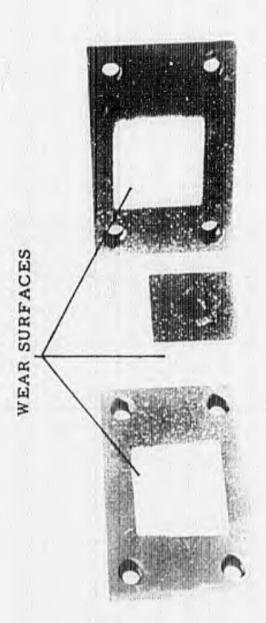


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U. S. ARMY - SPRINGFIELD ARMORY
SPRINGFIELD ARMORY FRICTION AND WEAR MACHINE WITH SUPPLEMENTARY INSTRUMENTATION









APPENDIX B - Tables

COEFFICIENT OF FRICTION FOR DRY MANGEMESE PHOSPHATE 71.5.2 7 COATINES 548710

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ACTUAL NORMAL FORCE	32.1	431	18	1:99	1.91	1:18	1 86	1.601	1:00	131.1	148.1	1831	1841	121	1981	1.461
LOBO DOUIED TO LEVER	0	`	A.	<i>w</i>)	*	<i>y</i>	0	<u> </u>	٥,	0	0	1	3	<i>\$</i> 2	7	15

MEAN COEFFICIENT FOR BLL THIMIS KGUMIS .876 STANDORD GEVIATION FROM THE MEAN KGUALS +.028 () the person throwwise CHANGED FROM !

To 4 Schole

FACT PHATE CONTINGS

TRIME TREATY TRIME 2 TRIME 3 TRIME 44 TRIME NAME TREATY TRIME 2 TRIME 3 TRIME 44 TRIME NAME TREATY TRIME 2 TRIME 3 TRIME 44 TRIME NAME TREATY TRIME TREATY TRIME 3 TRIME 44 TRIME NAME TREATY TRIME TREATY TRIME 3 TRIME 44 O 32 35 14 45 18 4 16 25 14 I 45 475 14 65 19 6 17 5 15 3 65 75 14 75 18 7.25 17 6.5 15 3 65 75 14 95 18 10 16 9 15 5 87 9 15 14 15 18 11 16 10.5 15 6 98 1125 14 15 18 11 16 10.5 15 6 98 1125 14 15 18 11 16 10.5 15 7 109 12.75 5 14 16 14 16 13.5 16 8 120 145 15 15 15 15 16 15.5 16 10 10 11 17 15 17.5 15 15 15 16 15.5 16 10 11 133 17.5 14 18.5 15 15 16 15.5 16 11 133 17.5 14 18.5 15 15 16 15.5 16 12 144 18.5 14 20 15 20 15 15.5 15 13 15 19 14 21 15 22 15 14 194 20 13 21 15 22 15 15 197 20.5 14 23 15 24 15 16 20.1 20.5 14 23 15 24 15 17 219.1 20.5 14 26 14 26 15 265 15 18 20.1 20.5 14 26 14 26 15 265 15 18 20.1 20.5 14 26 14 26 15 265 15 18 20.1 20.5 14 26 14 26 15 265 15 18 20.1 20.5 14 26 14 26 15 265 15 20 2741 32 47 32 47 32 47 33 47 47 47 21 20.1 32 47 32 47 32 47 37 47 47 47 47 47 47		•		-			- 0.01, 1.15 67.	3		
THE TOTAL RECEIVED REAL TION OF THE PROPERTY O	Provide	NET SEL	TRI	1-2 /	TRI	92 2	7772	144 3	Tren	12 W
0 32 3.5	To	ED NORMAL	RECCRIPIN	Con Extense	PECCHOER		RECORDER		RECORDED	
0 321 25 14 45 19 46 19 19 19 19 19 19 19 19 19 19 19 19 19	ARM	1	DEFLECTION	(CDE / FEIEN	GELECTION	LOE: FICIE	DEFLECTION	COEFFICIEN	~	CUEFFICIENT
2 541 6 14 75 19 6 17 5 15 2 541 6 14 775 18 725 17 65 15 3 661 75 14 95 18 85 16 25 14 4 761 85 14 11 18 10 16 9 15 5 871 915 14 125 18 11 16 10 5 15 6 981 1125 14 125 18 11 16 10 5 15 6 981 1125 14 13 17 1225 16 12 15 8 1201 145 15 15 15 16 15 16 135 16 1201 145 15 15 15 16 15 16 155 16 1201 145 15 15 15 15 16 15 16 155 16 1201 145 15 15 15 15 16 15 16 155 16 11 1531 17 16 16 165 165 16 1625 18 17 16 11 1531 175 14 185 15 15 185 15 18 17 16 11 1531 175 14 185 15 15 185 15 18 16 12 1641 185 14 20 15 20 15 18 18 15 14 1961 20 13 21 15 22 15 15 16 1971 215 14 21 15 24 15 22 15 16 1971 215 14 28 15 24 15 22 15 17 2191 225 14 28 15 27 15 28 15 19 2111 226 14 28 15 285 15 20 2321 275 14 28 15 285 15 21 2301 26 14 28 15 28 15 29 15 22 2751 32 16 32 17 32 17 35 18 23 271 32 17 32 17 32 17 35 30 15 24 2321 275 14 28 15 38 15 24 241 38 15 39 15 25 301 38 5 14 31 15 30 15 26 3021 275 14 31 15 30 15 27 2791 32 16 32 14 31 15 30 15 28 301 38 5 14 31 17 35 30 15 29 2791 32 16 32 14 31 15 30 15 20 3791 33 15 14 31 17 35 30 15 21 3631 38 17 32 14 35 13 365 14 38 15 21 3731 48 34 14 36 13 38 14 39 14 21 3511 41 15 37 14 38 13 37 14 30 3651 41 16 17 14 38 13 37 14 31 3731 42 14 38 14 40 14 40 14 40 14 31 461 485 14 48 14 48 14 44 44 34 4661 485 14 48 14 48 14 44 44 34 4661 485 14 48 14 48 14 44 44	0	1 00	3.5	.14	4.5	.18				
3 65 75 14 9.5 18 8.5 16 7.5 14 4 76 8.5 14 11 18 10 16 9 15 5 87 9.5 14 13 17 12.25 16 12.5 14 6 98 11.25 14 13 17 12.25 16 12.5 16 7 109 12.75 15 14 15 16 14 16 13.5 16 8 120 14.5 15 15 15 16 15.5 16 15.5 16 9 131 16 16 16.5 14.5 16 15.5 16 17 16 10 142 17 15 14 18.5 15 17.5 17.5 17.5 18 18 16 11 133 17.5 14 18.5 15 18.5 16 17.5 18 18 16 12 144 18.5 14 20 15 20 15 15.5 15 3 175 17 14 18.5 15 18 18 16 14 18.5 14 21 15 22 15 15 15 3 175 17 14 21 15 22 15 23 15 22 15 3 175 17 21.5 14 21 15 23 15 22 15 18 1971 21.5 14 22 15 23 15 22 15 18 2061 20.5 14 24 14 25 15 27 15 28 15 19 24.1 20 23.5 23 25 14 36 15 24 15 19 24.1 25 14 26 14 26 14 26 14 26 14 27 15 28 15 21 26.1 25 14 26 14 26 14 27 15 28 15 22 24.1 32 31.5 34 34 34 34 34 34 34	. /	-	4.75	.14	\$5	19		.17	5	
3 65 75 14 9.5 18 8.5 16 7.5 14 4 76 8.5 14 11 18 10 16 9 15 5 89 9/5 14 13 17 12.25 16 12 15 6 98 11.25 14 13 17 12.25 16 12.5 16 7 109 12.75 15 15 15.5 16 14 16 13.5 16 8 122 14.5 15 15.5 16 15 16 15.5 16 9 131 16 16 17 16 17.5 17 17 18 17.5 17 18 18 18 18 10 14/1 18.6 14 20 15 20 15 18 15 18 15 11 153 175 14 18.5 14 20 15 20 15 18 15 18 15 12 16/1 18.6 14 20 15 20 15 18 20.5 15 3 175 17 21.5 14 21 21 21 22 25 25 3 175 20 13 22 15 23 15 22 15 4 1971 21.5 14 23 15 24 15 22 15 16 20.1 22.5 14 24 14 25 15 22 15 17 219 23.5 13 25 14 26 14 26 15 265 15 18 23.1 25 14 26 14 26 14 27 15 28 15 20 23.2 275 14 22 14 31 15 30 15 21 363 27 44 28 14 31 15 32 15 22 274 29 14 31 15 33 15 15 23 27 37 38 14 32 17 38 13 36 14 37 15 24 384 38 14 32 13 36 14 37 18	2	541	6	14	775	.18	7.25	.17	6.5	•
4 761 8.5 14 11 18 10 16 9 15 5 871 975 14 125 18 11 16 105 15 6 981 1125 14 13 17 225 16 12 15 7 1091 12.75 15 15 15 16 14 16 12.5 16 8 1221 14.5 15 15.5 16 15 16 15.5 16 9 131 16 16 16.5 16 15 16 15.5 16 17 16 10 1421 16 16 16.5 16 15.5 16 17 16 10 1421 16 16 16 15 16 17 16 16 10 1421 16 16 16 16 16 17 16 16 16 16 16 16 16 16 16 16 16		651	75	14	9.5	18	8.5	16		_
6 981 195 14 125 18 11 16 105 13 17 225 16 12 15 16 18 11 16 105 16 12 15 16 12 15 16 12 15 16 12 15 16 16 15 16 125 16 16 16 15 16 15 16 15 16 15 16 15 16 15 16 15 16 15 16 15 16	4	76 1	8.5	.14	11	.18	10	.16		
6 96 125 14 13 17 12.25 16 12 15 7 109 12.75 15 15 14 16 14 16 13.5 16 8 120 14.5 15 15 16 15 16 155 16 9 13.1 16 16 16 15 16 15 16 17 16 10 142 17 15 16 15 16 15 16 17 16 10 142 17 16 165 15 16 17 16 11 153.1 17 16 165 15 16 17 16 11 153.1 17 16 16 20 15 18 16 11 16.1 18 14 20 15 20 15 18 15 12 17.1 20 13 21 1	5	87.1	915	.14	125	.18	11	.16	105	.15
9 109 12.75 15 14 16 14 16 13.5 16 8 120 14.5 15 15 15.5 16 15 16 15.5 16 9 131 16 16 16.5 16 15 16 15.5 16 17 16 10 142 17 15 18.5 15 18.5 15 18 15 18 16 11 1531 17.5 14 18.5 15 18.5 15 18	6	981	1125	.14	13	.17	12.25	16	12	
8 120 144.5 1.5 1.5 1.6 1.5 1.6 1.5.5 1.6 9 131 16 1.6 1.6.5 1.16 1.6.25 1.16 1.7 1.16 10 142 17 1.7 1.5 1.7.5 1.4 1.6.5 1.7 1.7 1.6 11 153 17.5 1.4 1.8.5 1.5 1.8 1.6 1.6 1.6 11 153 17.5 1.4 1.8.5 1.4 1.8.5 1.5 1.8 1.6 1.5 1.6 1.2 1.5 1.5 1.6 1.2 1.5 1.5 1.5	7	1091	12.75	115	14	.16	14	15	13.5	
9 131 16	ER	120 1	14.5	15	15.5	16	15	.16	15.5	.16
10 11 17 18 18 18 18 18 18	9	131 1	16	15	16.5	.16	16.25	. 100	17	.16
15 1641 18.5 14 18.5 15 15 15 15 15 15 15	10	1421	17	.15	11.5	.15	17.5	.15	18	
19 1641 18.5 14 20 15 20 15 19.5 15 3 1151 19 .14 21 .5 32 .16 20.5 .15 11 1961 20 .13 22 .15 23 .15 22 .15 15 1971 21.5 .14 23 .15 24 .15 24 .15 16 20.61 22.5 .14 24 .14 25 .15 17 219.1 23.5 .13 25 .14 26 .15 265 .15 18 230.1 25 .14 26 .14 27 .15 28 .15 19 241.1 26 .14 28 .15 28.5 .15 29.5 .15 20 23.21 27.5 .14 29.5 .14 31 .15 30 .15 21 363.1 28.5 .14 29 .14 31 .15 30 .15 22 2741 39 .15 30 .14 31 .15 30.5 23 285.1 31.5 14 31 .14 34 .15 33.5 .15 24 396.1 33 .14 32 .14 35 .13 36 .15 34 .14 25 3071 34.5 .14 35 .13 36.5 .14 38 .14 26 318.1 36 .14 35 .13 36 .15 36 .15 21 329.1 37 .14 35 .13 36.5 .14 38 .14 22 3401 38 .14 36 .13 36 .14 39 .44 23 351.1 41 .15 37 .13 39 .14 39 .44 30 362.1 41 .14 38 .13 39 .14 41 .15 31 373.1 42 .14 39.5 .13 39 .14 41 .15 32 386.1 413 .14 412 .14 414 .14 33 395.1 44.5 .14 412 .44 444 .44 34 416.1 415.5 .14 413 .14 412 .44 444 .44 34 416.1 415.5 .14 413 .14 412 .44 414 .44 34 416.1 415.5 .14 413 .14 415 .13 414 .14 415.5 .14	11	153 /	17.5	14	18.5	.15	18.5	.15		
3 175 19 .14 21 .75 22 .16 20.5 .15 IN 196 20 .13 22 .15 23 .15 22 .15 IS 1971 21.5 .14 23 .15 24 .15 24 .15 IS 205.1 .25 .14 24 .14 .25 .15 .25 .15 17 219.1 23.5 .13 .25 .14 .26 .15 .26 .15 .26 .15 .26 .15 .26 .15 <t< td=""><td>12</td><td>1641</td><td>19.5</td><td>.14</td><td>20</td><td>15</td><td>20</td><td>.15</td><td></td><td></td></t<>	12	1641	19.5	.14	20	15	20	.15		
14 1961 20 13 22 15 23 15 22 15 16 1971 21.5 14 23 15 24 15 24 15 16 208.1 22.5 .14 24 .14 25 15 25 .15 17 219.1 23.5 .13 25 .14 26 .19 27 .15 28 .15 18 230.1 .25 .14 26 .19 27 .15 28 .15 19 241.1 .26 .14 .26 .19 27 .15 28 .15 20 241.1 .26 .14 .26 .19 .27 .15 28 .15 20 241.1 .26 .14 .26 .19 .27 .15 .28 .15 20 241.1 .26 .14 .26 .14 .31 .15 .30 .15 21 .263.1 .27 .14 .26 .14 .31 .15 .31 .15 .31 .15 22 .274.1 .32 .14 .31 .14 .34 .15 <td>. E</td> <td>1751</td> <td>19</td> <td>.14</td> <td>21</td> <td>15</td> <td>22</td> <td>.16</td> <td>20.5</td> <td></td>	. E	1751	19	.14	21	15	22	.16	20.5	
	14	1661	20	.13	22	15	23	.15		
18 208.1 22.5 .14 24 .14 25 .15 25 .15 17 219.1 23.5 .13 25 .14 26 .15 265 .15 18 230.1 25 .14 26 .14 28 .15 28.5 .15 28 .15 19 241.1 26 .14 28 .15 28.5 .15 29 .15 20 241.1 26 .14 28 .15 28.5 .15 29 .15 21 263.1 27.5 .14 29 .14 31 .15 30 .15 21 263.1 27.5 .14 29 .14 31 .15 31.5 .15 22 274.1 32 .15 32 .15 32 .15 22 274.1 32 .14 34 .15 33.5 .15 24 296.1 33 .14 32 .14 35 .15 34 .14	15	1971	21.5	.14	23	.15	27	.15	24	***
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	18	208.1	22.5	.14	24	.14	35			**
IF 230.1 25 14 26 .14 27 .15 28 .15 19 241.1 26 .14 28 .15 28.5 .15 29.5 .15 20 25.2 1 27.5 .14 29 .14 31 .15 30 .15 21 263.1 27.5 .14 29 .14 31 .15 31.5 .15 22 274.1 32 .15 32 .14 32 .15 33 .15 22 275.1 31.5 .14 31 .14 34 .15 33.5 .15 22 275.1 31.5 .14 31 .14 34 .15 33.5 .15 24 296.1 33 .14 32 .14 35 .15 34 .14 25 307.1 34.5 .14 33 .13 36 .15 34 .14 26 318.1 36 .14 35 .13 36.5 .14 38 .14 28 340.1 38 .14 36 .13 36 .14 39 .14	17	219.1	23.5	113	25	.146	26	-15		
19 241.1 26 14 28 15 28.5 15 29.5 15 20 23.21 27.5 14 28.5 11 31 15 30 15 21 263.1 27.5 14 29 14 31 15 31.5 15 22 27.41 32 15 32 14 32 15 23 15 23 285.1 21.5 14 31 14 34 15 33.5 15 24 296.1 33 14 32 14 35 15 34 14 25 3071 34.5 14 33 13 36 15 36 15 26 318.1 36 14 35 13 36.5 14 37 16 27 329.1 37 14 36 13 38 14 38 14 28 3401 38 14 36 13 38 14 49 14 </td <td>16</td> <td>230-1</td> <td>25</td> <td>14</td> <td>26</td> <td>.14</td> <td>27</td> <td>.15</td> <td></td> <td>-</td>	16	230-1	25	14	26	.14	27	.15		-
20 202 27.5	19	241.1	26	.14	28	.15	28.5	.15		
21 363.1 28.5 14 29 14 31 15 31.5 15 22 2741 32 15 30 14 31 14 32 15 33 15 22 285.1 31.5 14 31 14 34 15 33.5 15 24 296.1 33 14 32 14 35 15 34 14 25 3071 34.5 14 33 13 36 15 36 15 26 318.1 36 14 34 13 36.5 14 37 15 27 329.1 37 14 35 13 36.5 14 38 14 28 3401 38 14 36 13 38 14 39 14 29 351.1 41 15 37 13 39 14 11 15 30 362.1 41 14 38 13 40 14 42 15 31 373.1 42 14 39.5 13 41 14 42 14 32 385.1 445 14 42 14 42 14 44 14 33 395.1 44.5 14 42 14 42 14 44 14 34 466.1 45.5 14 43.5 13 49 14 44 14	20	2321	27.5	.14	285	.14	31	.15		
22 274 32	21	263.1	2F.5	.14	29	.14	31	.15	31.5	
2? 285.1 31.5 14 31 14 34 .15 33.5 .15 24 296.1 33 .14 32 .14 35 .15 34 .14 25 3071 34.5 .14 33 .13 36 .15 36 .15 26 318.1 36 .14 34 .13 36.5 .14 37 .15 27 329.1 37 .14 35 .13 37.5 .14 38 .14 28 3401 38 .14 36 .13 38 .14 39 .14 29 351.1 41 .15 37 .13 39 .14 41 .15 30 382.1 41 .14 38 .13 40 .14 42 .15 31 373.1 42 .14 39.5 .13 41 .14 42.5 44 32 381.1 43 .14 442 .14 42 .14 44 .14 33 395.1 44.5 .14 44.5 .13 44 .14 44 .14 34 406.1 45.5 .14 43 .13 44 .14 45.5 .14	22	2741	32	.15	30	114	32	15		
24 296.1 33 14 32 .14 35 .15 34 .14 25 3071 34.5 .14 33 13 36 .15 36 .15 26 318.1 36 .14 34 .13 36.5 .14 37 .15 27 329.1 37 .14 35 .13 37.5 .14 38 .14 28 340.1 38 .14 36 .13 38 .14 39 .14 29 351.1 41 .15 37 .13 39 .14 41 .15 30 362.1 41 .14 38 .13 40 .14 42 .15 31 373.1 42 .14 39.5 .13 40 .14 42.5 .14 32 381.1 43 .14 42 .14 42 .14 .14 .14 32 395.1 44.5 .14 42 .14 44 .14 .14 34 406.1 405.5 .14 413 .13 44 .14 .14 .14	23	285.1	31.5	14	31	14	3.41	.15		
25 3071 34.5 14 38 13 36 .15 36 .15 26 318.1 36 .14 34 .13 36.5 14 37 .15 27 329.1 37 .14 35 .13 37.5 .14 38 .14 28 3401 38 .14 36 .13 38 .14 39 .14 29 351.1 41 .15 37 .13 39 .14 41 .15 30 362.1 41 .14 38 .13 40 .14 42 .15 31 373.1 42 .14 39.5 .13 41 .14 42.5 14 32 381.1 43 14 42 .14 42 .14 44 .14 33 395.1 44.5 .14 425 .13 43 .14 44 .14 34 446.1 45.5 .14 43 .13 44 .14 45.5 .14	24		33	.14	32	. 14	35	.15	24	
26 318.1 36 14 34 13 36.5 14 37 18 27 329.1 37 14 35 13 37.5 14 38 14 28 340.1 38 14 36 13 38 14 39 14 29 351.1 41 15 37 13 39 14 41 15 30 362.1 41 14 38 13 40 14 42 15 31 373.1 42 14 39.5 13 41 14 42.5 14 32 381.1 43 14 42 14 44 14 32 395.1 44.5 14 43 13 43 14 44 14 34 406.1 45.5 14 43 13 44 14 45.5 14	25	3071	34.5	14	35	13	36	.15		
27 329.1 37 .14 35 .13 37.5 .14 38 .14 28 340 1 38 .14 36 .13 38 .14 39 .14 29 351.1 41 .15 37 .13 39 .14 41 .15 30 362.1 41 .14 38 .13 40 .14 42 .15 31 373.1 42 .14 39.5 .13 41 .14 42.5 .14 32 381.1 43 14 42 .14 42 .14 44 .14 33 395.1 44.5 .14 435 .13 43 .14 44 .14 34 406.1 45.5 .14 43 .13 44 .14 45.5 .14				.14	34	.13	36.5			
28 340 1 38 .14 36 .13 38 .14 39 .44 29 351.1 41 .15 37 .13 39 .14 41 .15 30 362.1 41 .14 38 .13 40 .14 42 .15 31 373.1 42 .14 39.5 .13 41 .14 42.5 .44 32 381.1 43 .14 42 .14 42 .14 42 .14 44 .14 33 395.1 44.5 .14 425 .13 43 .14 44 .14 34 406.1 45.5 .14 43 .13 44 .14 46.5 .14		329.1	37	.14	35	.13	37.5		•	4
29 351.1 41 .15 37 .13 39 .14 41 .15 30 362.1 41 .14 38 .13 40 .14 42 .15 31 373.1 42 .14 39.5 .13 41 .14 42.5 .14 32 381.1 43 .14 42 .14 42 .14 44 .14 32 395.1 44.5 .14 43.5 .13 43 .14 44 .14 34 406.1 45.5 .14 43 .13 44 .14 46.5 .14		3401		.14	36	.13	38	. 141		
30 362.1 41 .14 38 .13 40 .14 42 .15 31 373.1 42 .14 39.5 .13 41 .14 42.5 .44 32 381.1 43 .14 42 .14 42 .14 42 .14 44 .14 33 395.1 44.5 .14 425 .13 43 .14 44 .14 34 406.1 45.5 .14 43 .13 44 .14 46.5 .14	29	351.1	41	15	37	.13	39	.14		
31 383.1 42 .14 39.5 .13 41 .14 42.5 14 32 381.1 43 .14 42 .14 42 .14 44 .14 33 395.1 44.5 .14 42.5 .13 43 .14 44 .14 34 406.1 45.5 .14 43 .13 44 .14 45.5 .14	30		41	14	38	.13		-		
32 381.1 43 14 42 .14 42 .14 44 .14 33 395.1 44.5 .14 425 .13 43 .14 44 .14 34 406.1 45.5 .14 43 .13 44 .14 45.5 .14	3/	373.1	42	.14	39.5	.13	311			
33 395.1 44.5 .14 435 .13 43 .14 44 .14 34 406.1 45.5 .14 43 .13 44 .14 45.5 .14	.32	381.1	43	14	1/2					
34 406.1 45.5 .14 43 .13 44 .14 45.5 .14	33	395.1	44.5	.14	1625	.13				
مسمر فقدرف المراس	34	406.1	35.5	.14	43					
33 411.1 49 .14 45 .14 45 .14	35	417.1	47	. 14	45	-144	15			

MEAN COEFFICIENT FOR ALL TRIBLS EQUALS . 147
STANDARD DEVIATION FROM THE MEAN EQUALS : . 011

TABLE IV

SINTIC CCERTICIENT OF FRICTION FOR OILEO ZINC

LONG	Henry	TRIBL	1	TRI	12 2	TRIA	و بر	TRI	Bd. ga
10	A PARISE	RECORDER		RECORDER	** **********************************	RECONDER		RECOUNTE	
AMM		DEFLECTION	OF A FICIE	OF FLECTION	COEFFICIA	DEFLECTION	CARLICIE	RECORDER DEFLECTION	CONFFICIENT
0	30 /	.3	112	ď	.12	3.5	114	3.25	.13
/	431	4.25	.1.2	4.25	.12	4.75	. 4	4175	.14
2	541	5.75	.13	5.5	13	6	.14	6	. 14
2	65.1	7	.13	6.75	.13	7.5	.14	7	.13
4	761	7.5	.13	B	3	8.5	1-12	8.25	.14
5	871	10	.14	9.R5	.13	10	· rugh	95	. 12.80
6	98 1	11.5	.15	10.5	-1.3	11	114	11	.14
7	109:	15	.15	11.75	.14	12.5	.1.4	12.25	1.84
E	120/	15	16	12.75	13	13.5	· hot	13 75	14
9	13/1	165	.16	14	1.3	14.5	.14	15	. 141
16	142.1	18.5	160	15	.13	15.75	.14	16.5	.15
11	153.1	20	.16	16.25	.13	17	.14	18	.15
12	1641	22	17	17.5	.13	18	.19	19	.15
13	175.1	24	17	18.75	.13	19.5	14	21	.15
14	186.1	26	.17	20	.13	.20.5	14	22	.15
15	1971	28	.18	21	. 13	22	.14	23.5	.15
16	20,61	295	.18	<i>સ્વ</i>	.13	23	14	25	.15
17	219.1	31	.18	23	.13	24	-146	26	.15
18	230 1	32	.17	24	.13	25.5	.14	25	.15
19	241.1	.23	.17	25.5	.13	27	. 14	29	.15
20	255.1	340	.17	27	.13	28	salge	30	15
21	W.J./	35.5	17	-28	. 9 2	29.5	.14	9/	.15
22	274.1	3%	.17	29.5	.13	30.5	-14	32	.15
23	2851	35.5	.17	30.75	14	32	11	34	.15
24	0296 1	40	.17	34	.14	3.3	.14	35	.15
-25	307.1	41.5	17	34	.14	34	1.4	36	. 15
26	318.1	10.50	17	34.5	.14	55.5	. 146	37	.15
27	529.1	11.25	.17	35.5	.14	37	.14	38.5	.15
20	340/	1150	.17	36.5	.13	38	.14	40.5	.15
29	351.1	11.75	.17	37	.13	39	-146	41	.15
30	3601	12	-17	39	1.91	40	.14	432	.15
3/	373.1	12.5	-17	42	. 14	11.5	- styl	43.5	.15
22	384.1	13	17	43	. 156	140.5	150	44.5	.15
40	395.1	13.5	.17	44.5	.14	43.5	14	46	. 15
54	406 1	14	17	46	. 140	44.5	.14	47	.15
35	417.1	14.5	.17	47	. 14	345	.14	48.5	.15

NEAN COEFFICIENT FOR ALL TRIALS EQUALS . 145 STANDARD DEVIATION FROM THE MEAN EQUALSTOICE

NOTES O HIMPLIFER ATTENUATOR CHANGED FROM 1 TO 4 SCALE

	FRICTION
	00
	COEFFICIENT
	STATIC
Z 378	ON
TABLE	ROUGHNESS
	SURFACE
	90
	EFFECT

CECT ELAST - MINTY WE SO AND SE STEEL RELIGIONNESS REPONDE BETORE PHOSONOTING AFTER P	4 5 5 4 4 1 8 2 8 9 8 8 8 8 8 8 8 8 8 9 9 8 8 8 9 9 8 8 8 9 9 8 8 8 9 9 8 8 9 9 8 8 9 9 9 9 8 8 9 9 9 9 8 9
46 50 440 60 440	#6.50 #1050 #6.50 #1050 #6.50 #1050 #6.50 #1050 #6.50 #1050 #6.50 #106 #6.50 #106 #
	S. C.
	157.18.18.18.18.18.18.18.18.18.18.18.18.18.

TO # SCHUK Fr. I. S. MET. K. CHANGEU FROM AMMIFIER HTTENUATOR 3 2.41.143 8,1115 000 NOTES:

PHOSOMOTE

MANGONIES

UKRE

ALL SOLCIMEAUS

SA-TRIB-1084

TABLE II

EFFECT OF SURFACE ROUGHNESS ON STATIC CO-

LONG	POTHAL NORMAL	TRIA	•	RECORDER	962
LEVER ARM	FORCE	DEFLECTION	COEFFICIE	OFFLE CTION	COEFFICIENT
0	30 1	4	16	5.5	.01
/	431	6	.17	7.5	.032
J	54.1	7	.16	9	.21
3	65.1	9	.17	11	21
apl	761	11	.18	12.5	.21
5	87.1	135	.19	14.5	.021
6	98.1	16	.20	17	.21
7	109.1	17.5	20	18.5	,02/
8	120.1	19	-20	20.5	-21
9	1311	21	.020	22.5	.2/
10	1421	#3.5	.02/	24	.21
11	153.1	25.5	.02/	86	-21
12	164.1	27	.20	38	.21
13	1751	29	. 2/	30	.02/
14	1861	31	.21	30	.22
15	1971	33	.02/	-23	021
16	208.1	35	.02/	36	
17	219.1	37	,2/	38	.082
18	230.1	39	~?/	39	.21
19	241.1	40	.02/	42	.28
20	252.1	42	.21	43	.021
		/	YEAN V	PLUE	.209

NOTES () ITAMEANESE PHOSPHATE SPECIMENS WITH OIL. VAPOR BLAST (ABRASIVE NO. 200) PREPARATION

٠			TABLE VIII				
2/6	COEFFICIENT	OR	FRICTION	For	COURSE	COURSE CRYSTALLINE PROSPHETE	PHOSOMPI
			COATINGS				

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4	21	NAKMAK	AFCORDA AFFUELT	ER LOEFEKIEHT ION	RECORDER		Meco		RECORDER	GEFFKIENT
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\$5 \text{54} \te	## 87 37 71 95 10 10 10 10 10 10 10 10 10 10 10 10 10	13.1	28		\$	22.	6	61.	_	20
## '81 37 11 9.5 19 10 ## 100 .66 11 18 13 175 18 18 18 18 14 17 185 17 18 15 17 185 17 185 16 17 185 17 185 17 185 18 17 185 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 18 1	#\$ \cdot \text{9} \cdot \text{9} \cdot \text{11} \text{9} \text{14} \text{9} \text{17}	1:18	3		15	Ä	, io	00	95	61
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13	13 .75 kg .69 12 17 t3 15 .76	78.1	700		001	99.	11	00	3	6/
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7, 78 16 75 17 165 94, 79 30 176 175 17 185 94, 78 30 176 20, 17 185 94, 78 30 175 20 176 20, 20, 20, 20, 20, 20, 20, 20, 20, 20,	7	1.85	Þ		H	11.	125	113	14.5	8/
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24	21 .80 20 .76 175 17 19 22 .76 .20 .77 .25 24 .78 .25 .75 .20 .76 .24 25 .80 .27 .77 .23 .76 .24 26 .81 .85 .75 .24 .25 26 .81 .35 .75 .24 .25 27 .45 .25 28 .81 .30 .76 .45 .25 29 .76 .25 20 .76 .25 2	1.014	61		200	.75	19	11	81	8
44	## 76 44 17 025 94 78 93 75 20 16 92 96 77 77 93 16 94 96 97 77 93 16 94 96 91 95 77 93 16 97 98 91 30 74 95 16 39 99 16 39 MEAN VALUE 766 1769 VALUE 178	131.1	100		00	1/2	17.5	11	61	8%
44	34 76 33 .75 20 .16 32 34 .79 35 .75 20 .16 34 35 .80 37 .77 33 .16 34 35 .81 35 .74 35 .16 39 35 .81 30 .74 30 .16 33 MEAN VALUE .746 .178	1871	Å		a	8	61	11.	23	41.
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36	36 .80 an .77 an .46 an .53 .76 an .53 .75 an	1:491	8		225	2%	21.5	10	40	1
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	VALUE . TEG MEAN VALUE . 178	1:250	•				32	9/-	85	.61.

NOTES: O HAY I LEVER HATENUATOR CHANGED FROM 1 TO & SCALE.

TABLE VIII

DYNAMIC COLERICIENTS OF FRICTION FOR LUBRICATIO

	D Dik	CAINETE	Prospy	ATE COAT	1105
		TRINS			
LONG APPLIAD TO LEVER PART IN LES	NOTHAL NORMAL CORES	RESPROCE DESTA FION PT MO-STATEMA	Coeppellier	MAX. RECORDER TORRESTION (mm)	COLLEGION
0		3	12	5	./5-
	30/		11	12	.16
5	E1 /	A			_
10	142 /	11	.10	18	.15
15	197.1	.30	.18	30	19
AC.	250 /	24	.12	28	.13
عوه	307.1	29	.12	.35	.14
		77	-		
TO LAVER ARM		DEFLECTION AT	CEFFICIENT	PARA TECTION	CONFRICIENT
IN LES.	14 4 65.	MIO-STRAKE(NO)		(mini)	_
0	30/	4	.15	6	.19
5	87.1	8	.11	13	.17
10	1451	12	.11	20	.17
15	197.1	34	.21	كالهاطئ	.21
20	252/	25	.12	29	.14
سيج	30 77	28	.11	33	.13
		TRIA	1 3		
NOAU APPLIED	Brille.	RECORDER		MAN. ALCOESER	
TO LEVER PON	NORMAL FOREST		COEFFICIEN		COFFFICIENT
	32.1	3	12	3	16
ح	871	8	.11	13	.17
10	1421	11	.10	20	.17
15	1971	32	.20	32	.20
20	252 1	05	.12	31	.15
25	3091	31	.13	36	سىر.
			10 mg		
LONO APALIED	ACTURL	REGORDER	- 7	May Astrones	
TO LAUFER BAM	NORMAL FORCES	OFFIECTION AT	COEFFICIEN		COEFFICIENT
IN L85	111185	MID STREEKE (1949)		(mm)	
0	30/	3	.12	5	16
5	871	8	11	11	.14
10	142.1	11	.10	20	.17
15	197.1	53	.20	33	.20
20	252.1	26	.13	32	15
25	307.1	29	.12	34	.15
		TRI	1 1 5		
LOND BANKED TO LEVER PAM	NORMAL PORCE	RECORDER AT		MAK RECORDER T OKFLECTION	CORRECCIONT
12/ 1.85	INLES	HID-STARKE (MAN)	10	(mm)	.16
0.	50/	<i>3</i>	.12	5	-14
5	87.1	7	.10	11	
10	1421	11	.10	18	.15
15	1971	33	.21	33	-21
20	252.1	26	.13	31	1150
25	307.1	30	12	37	.15
WIEDN	CAFFEIC	IENTS	MILO S	TROKE 11	16

MID STROKE .116 MARKIMUM .153 MEAN COEFFICIENTS VALUES AT 15 LES. ARE NOT INCLUDED IN MEAN

STANDARD DEVIATION FROM THE MEAN FOR MAXIMUM DEFLECTIONS EQUALS T.046 -30 -

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DYCAMIC
                COEFFICIENTS
                                      OF
                                              FRICTION FOR LUBRILATED
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                               TRIAL.
  TO LEVEN FROM
                          PECOROFA
                                                   MAY RECORDER
                                                    OFFLECTION COEFFICIENT
              NORMAL FORE DEFLECTION COEFFICIENT
                          AT MAD STROKERING
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                 IN 285
                 20 /
       د٢
                               3
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                                                       مم
                                                                   .16
      5
                  871
                               7
                                           .10
                                                       11
                                                                    -14
                                                                   .16
      10
                  142.1
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                                                       19
                  197.1
                              32
       15
                                          .20
                                                       32
                                                                   .20
                 250.1
                                                       30
                                                                   .14
      20
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                                                                   .146
      25
                  307.1
                              30
                                          .12
                                                       35
                                 TRIAL 2
                          RECORDER COFFEREN
  LOND PROPLED BETTER LATER TO LEVER PORTE IN LASS IN LASS
                                                    YAK. RECORDER
                                                    OFFIECTION COFFEICIENT
                          AT MID STROKE
                 32.1
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                 3071
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                              30
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                                 TRIAL 3
  LOND HUPLIED ACTUAL RECORDER
TO LIVER AND NORMAN FORCE DEFLECTION AT LOFFFICIENT
IN LET. IN LES. MID GRANDER
  LORO HUPLIED
                                                   MAY. RECORDER
                                                   DEFIECTION COEFFEIENT
                 32.1
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 LOND ABALLED ACTUAL
    OMO AMALIED ACTUML PORCE DEFECTION AT COEFFICIENT
                                                  MAR. ASCORDED COFFFICIENT
    IN 185.
                14 L85
                         MID STRUKE (mm)
      0
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                                                                  .16
      5
                 87.1
                              8
                                          -11
                                                       11
                                                                  .14
                1421
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                                          .11
      10
                                                       20
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      15
                 197.1
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                                                                  12/
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                 252/
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     ..75
                             #9
                 307.1
                                                       34
                                          12
                                                                  .14
                                  MID
  MEAN
           COEFFICIENTS
                                         STROKE
                                 MAXIMUM
                                                     .150
                                   NOT INCLUDED IN MEAN
 VALUES AT 15 L85 ARE
STANDARD DEVIATION FROM THE MEAN FOR
                                                                  MAKIMUM
     DEFLECTIONS
                        FOUALS 5.010.
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TABLE IX

SATRIS-1084

APPENDIX C

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was independent of the applied load. Velocity during dynamic testing, differ to any practical extent from the coefficients for zinc phosfriction are considered: type of coaring, lubrication, loading weight, surface roughness, crystalline structure, and velocity. The conditions. The following factors influencing the coefficient of components. The machine was used to evaluate the various factors to simulate the frictional characteristics of reciprocating weapon A friction and wear machine has been developed at Springfield Armory surface finish, and crystalline structure influenced the coefficient to a slight degree. Procedure is given, and results are discussed. cients of friction for phosphate coatings. The coefficient of friction phase coatings. Lubrication is a significant factor on the coefficoefficients of friction for mangenese phosphate coeffings did not friction for the coatings were determined under static and dynamic influencing the friction of phosphate coatings. Coefficients of

> Friction and Wear * FACTORS INFLUENCING FRICTION OF PHOSPHATE COATINGS, by Michael Springfield Armory, Springfield, Mass.

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Phosphace

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Small Arms Lubrication

Small Arms A friction and wear machine has been developed at Springfield Armory efriction for the coatings were determined under static and dynamic "influencing the friction of phosphate coatings. Coefficients of to simulate the frictional characteristics of reciprocating weapon The machine was used to evaluate the various factors

ecients of friction for phosphate coatings. The coefficient of friction econditions The following factors influencing the coefficient of "to a slight degree. Procedure is given, and results are discussed differ to any practical extent from the coefficients for zinc phoswas independent of the applied load. Velocity during dynamic testing, phate coatings. Lubrication is a significant factor on the coeffifriction are considered: type of coating, lubrication, loading surface finish, and crystalline structure influenced the coefficient coefficients of friction for manganese phosphate coatings did not weight, surface roughness, crystalline structure, and velocity. Ihe

George, Technical Report SA-TR18-1084, 9 April 1964, 38 pages including tables and illustrations. CHS Code 5016.11.84400.02. Springfield Armory, Springfield, Mass. PRON. M1-3-50015-02-M1-M6. FACTORS INFLUENCING FRICTION OF PHOSPHATE COATINGS, by Michael A.

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cients of friction for phosphare coatings. The coefficient of friction was independent of the applied load. Velocity during dynamic testing. phate coatings. Lubrication is a significant factor on the coeffidiffer to any practical extent from the coefficients for zinc phosweight, surface roughness, crystalline structure, and velocity. The coefficients of friction for manganese phosphate coatings did not friction are considered: type of coating, lubrication, loading friction for the coatings were determined under static and dynamic A friction and wear machine has been developed at Springfield Armory components. to simulate the frictional characteristics of reciprocating weapon surface finish, and crystalline structure influenced the coefficient conditions. influencing the friction of phosphate coatings. Coefficients of The machine was used to evaluate the various factors The following factors influencing the coefficient of Procedure is given, and results are discussed

Priction

West

Springfield Armory, Springfield, Mass. FACTORS INFLUENCING FRICTION OF PHOSPHATE COATINGS, by Michael A.

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and Wear

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Small Arms

to simulate the frictional characteristics of reciprocating weapon A friction and wear machine has been developed at Springfield Armory influencing the friction of phosphate coatings. Coefficients of conditions. friction for the coatings were determined under static and dynamic The following factors influencing the coefficient of The machine was used to evaluate the various factors

surface finish, and crystalline structure influenced the coefficient ecients of friction for phosphate coatings. The coefficient of friction was independent of the applied load. Velocity during dynamic testing. coefficients of friction for manganese phosphate coatings did not eweight, surface roughness, crystalline structure, and velocity. friction are considered: type of coating, lubrication, loading differ to any practical extent from the coefficients for sinc phosphate coatings Lubrication is a significant factor on the coeffi-The Small Arms

to a slight degree. Procedure is given, and results are discussed